National Aeronautics and
Space Administration

Educator Product	
Educators	Grades 5-8

PSA-2004-08-001-ARC

Educator Guide

Grades 5–8

Mathematics

Personal Satellite Assistant

psa.arc.nasa.gov

PSA Educator Guides are available in electronic format through NASA Spacelink--one of NASA's electronic resources specifically developed for the educational community.

This publication and other educational products may be accessed at the following address:

http://spacelink.nasa.gov/products

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Contents

The Personal Satellite Assistant Mathematics Educator Guide for grades 5–8 has been developed by the National Aeronautics and Space Administration (NASA) for the purpose of increasing students' awareness of and interest in robotics, engineering, and the many career opportunities that utilize science, math, and technology skills. The lessons are designed for educators to use with students in grades 5-8 in conjunction with the Personal Satellite Assistant (PSA) multimedia activities on the Personal Satellite Assistant Education Web site (http://psa.arc.nasa.gov/).

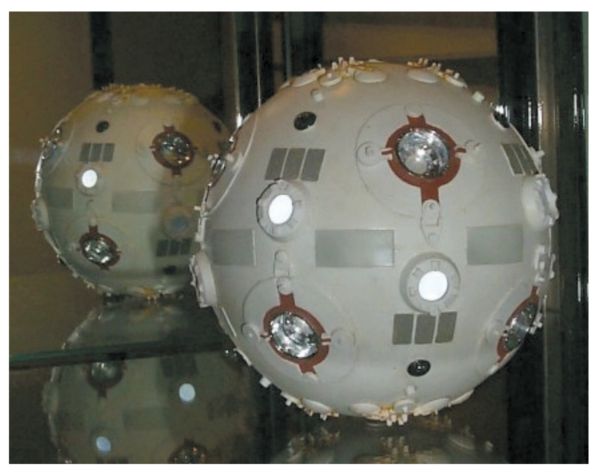
The lessons in this guide are designed to be used together to build a comprehensive understanding of forces and motion concepts. However, the lessons can also be used in isolation to focus on a particular concept.

Personal Satellite Assistant Overview

The Personal Satellite Assistant (PSA) is an intelligent, free-flying robot that NASA has been developing in an effort to improve how we explore and work in space. This spherical robot is being designed to fly around inside the International Space Station, as well as in spacecraft in orbit or traveling to the Moon or Mars. In addition, the control software and the vision system being developed and tested on the PSA can be used by many other kinds of robots, like future Mars rovers.

PSAs are designed to help people in three different ways. The first way is to do inspections and other tasks when the crew is too busy or when it is too dangerous. The second way is to help an astronaut perform tasks by acting as a laptop computer and cameraman that obeys voice commands and records what is being done, leaving the astronaut's hands free to do other things. The PSA has video conferencing capabilities that will allow engineers and scientists on Earth to interact with an astronaut in space. The third way is to diagnose problems on the spacecraft without having to bother the flight crew. If the spacecraft's sensors detect a problem, it can send a PSA to the location to determine the cause. If the cause is a failed sensor, in some cases the spacecraft can use a PSA as a temporary sensor until the spacecraft sensor is repaired. In addition, the spacecraft can use the PSA to track down the location of a heat source or a noise.

The design of the PSA was inspired in part by the small floating sphere that Luke Skywalker sparred with in the original "Star Wars" movie. Some of the PSA's capabilities were inspired by the "tricorders" that landing parties used to survey the atmosphere on planets in the TV series, "Star Trek." However, in space, astronauts like to keep their hands free to move around and perform tasks. The PSA has nine cameras to navigate and to record what is going on around it. Using its cameras, the PSA can figure out where it is and how fast is it moving. It can also avoid obstacles and follow targets. Like the fictional tricorder on "Star Trek," the PSA has sensors that detect the pressure and temperature of the air, as well as concentrations of gases such as oxygen and carbon dioxide. For astronauts living in a sealed aluminum can in the vacuum of space, this kind of information is essential. Additional special sensors could also be added as needed.



Jedi Training Remote
Star Wars, Lucasfilm

Mark X Tricorder
Star Trek, Paramount Communications Inc.

It is difficult to build a robot like this. Instead of trying to get the final robot design right on the first try, multiple robots are built, each being designed to answer a certain set of questions. Some of the models are non-functioning mockups to help understand how it should look and how people interact with it. Others are built to test certain subsystems, like propulsion. Others are fully functional prototypes, where each one is better than the one before it.

For the PSA prototypes to be operated in Earth's gravity, a special microgravity test mechanism was constructed. It looks like a bridge crane the size of a large room. The object (payload) suspended from it floats as it would in space. The crane has special sensors to detect any forces acting on the payload, and accelerates it into the direction of the net force so the payload continues to move in the same direction at a constant velocity, just as it would in space. By using the PSA as the payload, the PSA can fly around just as it would inside a spacecraft in orbit.

Future models of the PSA are being considered that have arms and that could help astronauts on the Moon and Mars. Robots continue to be a key strategic element for NASA to help humans living and working in space.

The PSA family of robot prototypes is being designed and built at NASA Ames Research Center in Mountain View, California. The latest status of its development will be posted at the PSA website.

PSA Web Site Overview

The PSA education Web site (http://psa.nasa.gov) has inquiry-based lessons, interactive multimedia activities, online challenges, and video animations focusing on systems, forces and motion, engineering design, volume, surface area, graphing, characteristics of 2-D and 3-D shapes, and center of mass. These are designed to support both middle school and high school students.

PSA Web Site
http://psa.arc.nasa.gov

NASA Relevance

NASA scientists and engineers working on the PSA project need to reduce the volume and mass of the PSA because of the high cost of transportation to the ISS, limited space in space-based vehicles, and for safety reasons. The PSA must move quickly and efficiently around the ISS in order to carry out its daily tasks. Thus, it must be designed with careful consideration of the fundamental principles of forces and motion.

PSA Web Site Overall Goal

Personal Satellite Assistant uses robotics engineering content, physics in the microgravity environment, problem-based learning, inquiry, and critical thinking skills to increase awareness of NASA careers and to educate students in grades 5-12 on the use of robotics to assist in space exploration missions.

PSA Web Site Overall Objectives

- Students in grades 5-12 will use problem-based learning and the engineering design process to design solutions for math and engineering problems related to the design of a robot that will operate in a microgravity environment.
- Students will observe and apply math patterns and relationships as they explore concepts such as unique properties of 3-D objects, surface area, volume, center of mass, and motion over time.
- Students will make observations of motion with very little or no friction, will draw conclusions about the laws of motion, and will describe and graph motion.
- Students will describe a NASA occupation that interests them.

Education Standards

In addition to meeting the National Council for Teachers of Mathematics, International Technology Education Association, and International Society for Technology in Education standards, PSA Educator Guides are written to meet benchmarks found in the Benchmarks for Science Literacy produced by the American Association for the Advancement of Science (AAAS) as part of their science, math, and technology reform movement called Project 2061. The mission of Project 2061 is to "shape the future of education in America, a future in which all students [will] become literate in science, mathematics and technology by graduation from high school" (p. VII).[1] "The Benchmarks for Science Literacy are statements of what all students should know or be able to do in science, mathematics and technology by the end of grades 2, 5, 8 and 12" (p. XI)[2] and are based on extensive research of when and how it is developmentally appropriate to teach the concepts and skills described.

The tables below show the benchmarks and standards for the PSA lessons. The first portion of the table entry identifies which standards or benchmarks are referenced. "2061" is a reference to the Benchmarks for Science Literacy. "NSES" is a reference to the National Science Education Standards. "ITEA" is a reference to the International Technology Education Association national education standards. "ISTE" is a reference to the International Society for Technology in Education standards. "NCTM" is a reference to the National Council for Teachers of Mathematics. The second portion of the table entry identifies the specific standard referenced. In the case of Project 2061, the standard is referenced, the grade range and then the number of the concept under this standard and grade range. We distinguish between "meeting" benchmarks or standards, "partially meeting" them, and "addressing" them to alert educators to concepts that are taught or partially taught for deep understanding in a lesson compared to topics or ideas that we might touch upon but do not really teach for deep understanding.

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[1] Project 2061, American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York. Oxford University Press. (p. VII).

[2] Project 2061. (p. XI).

PSA Middle School Math Objectives/Standards

Lesson	Main Concept	Objectives	Benchmarks/ Standards
1. Surface Area and Linear Dimensions of a Rectangular Prism	The surface area of a rectangular prism of fixed volume increases as you flatten it.	• Students will find the maximum surface area of a rectangular prism that has a volume of 24 cubic inches (393 cm^3) and fits into a sphere with a diameter of 8 inches (20 cm). • Students will write a letter to NASA engineers with the recommended dimensions for a computer for a PSA with an explanation of why this is the best solution. • Students will explain their recommendation of how to stack extra PSA computer components.	Meets: NCTM (6-8) Geometry #1, Measurement #2 2061: 9B (6-8) #2 Partially Meets: NCTM (6-8) Geometry #4 2061: 3B (6-8): #1 Addresses: NCTM (6-8) Measurement #1 2061: 2B (6-8) #1 2061: 9C (6-8) #1 ITEA 8 NSES E (5-8) #1
2. Surface Area, Volume, and Linear Dimensions of a Rectangular Prism	The surface area and volume of a rectangular prism change dispropor-tionately when the linear dimensions change.	• Students will use ratios to compare physical quantities. • Students will explain that the surface area and volume of solids change disproportionately when their linear dimensions change. • Students will make a recommendation as to which dimension of a computer should be doubled in order to double its volume and maximize its surface area.	Meets: NCTM (6-8) Geometry #1, Measurement #2 2061: 9B (6-8) #2 Partially Meets: NCTM (6-8) Numbers and Operations #1 NCTM (6-8) Geometry #4 Addresses: NCTM (6-8) Measurement #1 2061: 2B (6-8) #1

Lesson	Main Concept	Objectives	Benchmarks/ Standards
3. Surface Area, Volume, and Linear Dimensions of a Cylinder	The surface area of a cylinder is greatest when its height-to-radius ratio is either very large or very small.	• Students will explain that the surface area of a cylinder will change as the radius and height change, even when the volume remains the same. • Students will explain that the surface area of a cylinder is greatest when its height-to-radius ratio is either very large or very small. • Students will make a recommendation on which dimension of a cylinder in the PSA should be increased in order to maximize its surface area.	Meets: NCTM (6-8) Geometry #1, Measurement #2 2061: 9B (6-8) #2 Partially Meets: NCTM (6-8) Geometry #4 Addresses: NCTM (6-8) Measurement #1 2061: 2B (6-8) #1 2061: 9C (6-8) #1
4. Surface Area, Volume, and Radius of a Sphere	The surface area and volume of a sphere change disproportionately with radius.	• Students will explain that the surface area and volume of a sphere change disproportionately when the radius changes.	Meets: NCTM (6-8) Geometry #1, Measurement #2 2061: 9B (6-8) #1, 9C (6-8) #1 Partially Meets: NCTM (6-8) Geometry #4 2061: 3B (6-8): #1 Addresses: ITEA 8 NCTM (6-8) Measurement #1 NSES E (5-8) #1 2061: 2B (6-8) #1

More information on the benchmarks and standards referenced can be found at the following Web addresses:

Standard/Benchmark Title	Web Address
American Association for the Advancement of Science: Project 2061	http://www.project2061.org/
National Science Education Standards (NSES)	http://www.nap.edu/readingroom/books/nses/html/
National Council of Teachers on Mathematics (NCTM)	http://standards.nctm.org/index.htm
International Society for Technology in Education (ISTE)	http://cnets.iste.org/
International Technology Education Association (ITEA)	http://www.iteawww.org/TAA/TAA.html

Educational Standards List

Benchmarks for Science Literacy (2061)

2. The Nature of Mathematics

B. Mathematics, Science and Technology (6-8)

#1 Mathematics is helpful in almost every kind of human endeavor – from laying bricks to prescribing medicine or drawing a face. In particular, mathematics has contributed to progress in science and technology for thousands of years and still continues to do so.

3. The Nature of Technology

B. Design and Systems (6-8)

#1 Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials to be used, are unavoidable. Other constraints, including economic, political, social, ethical, and aesthetic ones, limit choices.

9. The Mathematical World

B. Symbolic Relationships (6-8)

#1 An equation containing a variable may be true for just one value of the variable.

#2 Mathematical statements can be used to describe how one quantity changes when another changes. Rates of change can be computed from differences in magnitudes and vice versa.

C. Shapes (6-8)

#1 Some shapes have special properties: triangular shapes tend to make structures rigid, and round shapes give the least possible boundary for a given amount of interior area. Shapes can match exactly or have the same shape in different sizes.

National Council for Teachers of Mathematics

Numbers and Operations (6-8)

#1 Understand numbers, ways of representing numbers, relationships among numbers, and number systems.

Geometry (6-8)

#1 Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

#4 Use visualization, spatial reasoning, and geometric modeling to solve problems.

Measurement (6-8)

#1 Understand measurable attributes of objects and the units, systems, and processes of measurement.

#2 Apply appropriate techniques, tools, and formulas to determine measurements.

International Technology Education Association

Design

Standard 8: Students will develop an understanding of the attributes of design.

National Science Education Standards (NSES)

Standard E: Science and Technology (5-8)

#1. Abilities of technological design